NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2842

THE PLANING CHARACTERISTICS OF A SURFACE HAVING

A BASIC ANGLE OF DEAD RISE OF 40° AND

HORIZONTAL CHINE FLARE

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SUMMARY

In order to determine the effects of increasing the angle of dead rise on the planing characteristics of horizontally flared prismatic surfaces, an experimental investigation has been conducted with a surface having a basic angle of dead rise of 40° and horizontal chine flare. Wetted length, resistance, center-of-pressure location, and draft were determined for speed coefficients up to 25.0 and trims up to 30°. Beam-loading coefficients ranged from 0.85 to 87.33 and keel-weeted-length—beam ratios extended generally to 7.0 and, in some cases, to higher values whenever conditions of load and spray permitted.

The data show that for a given trim the planing characteristics depend principally on lift coefficient. The experimental variation of the difference between chine and keel wetted lengths with trim has the same general trend as theory. An increase in angle of dead rise from 20° (NACA TN 2804) to 40° decreased the ratio of center-of-pressure location to mean wetted length and the extent of the pile-up of water but increased the friction drag. At trims of 24° and greater, friction drag is negligible and the resistances for those trims may be assumed equal to the load times the tangent of the trim angle.

INTRODUCTION

A general program of research on the planing characteristics of a series of related prismatic surfaces has been undertaken by the National Advisory Committee for Aeronautics and is described in reference 1. The primary objective of this program is an extension of the range of experimental data on planing surfaces to cover the high trims and loads of significance in the design of high-speed water-based aircraft.

The detailed scope of the program was established to include basic angles of dead rise up to 40°, trims up to 30°, wetted-length—beam

ratios up to 7.0, and Froude numbers based on beam up to 25.0. The principal planing characteristics to be determined for appropriate combinations of speed, load, and trim were resistance, center of pressure, draft, and wetted length.

The main purpose of this paper is to present the hydrodynamic force data for a planing surface having an angle of dead rise of 40° and horizontal chine flare. This cross section is of interest in view of the trend toward high angles of dead rise as a means for reducing impact loads of heavily loaded seaplanes. The chine flare is an effective means for controlling spray and has been found to increase the lift of a planing surface having dead rise. Similar data for a planing surface with an angle of dead rise of 20° and horizontal chine flare are presented in reference 1.

SYMBOLS

b beam of planing surface, ft

d draft at trailing edge (measured vertically from undisturbed water level), ft

g acceleration due to gravity, 32.2 ft/sec^2

l_c chine wetted length, ft

l_k keel wetted length, ft

l_m mean wetted length, $\dfrac{l_c + l_k}{2}$ for this model, ft

l_p center-of-pressure location (measured along keel forward of trailing edge of planing surface), $\dfrac{M}{\Delta \cos \tau + R \sin \tau}$, ft

M trimming moment about trailing edge of planing surface at keel, ft-lb

Δ vertical load, lb

F friction, parallel to planing surface, lb

R horizontal resistance, lb

R_e Reynolds number, $\dfrac{V_m l_m}{\nu}$

S principal wetted area (bounded by trailing edge, chines, and heavy spray line) projected on plane parallel to keel, $l_m b$, sq ft

S_f actual wetted area aft of the stagnation line, sq ft

V horizontal velocity, ft/sec

V_m mean velocity over planing surface, $\sqrt{V^2\left(1 - \dfrac{C_{L_b}}{\cos \tau \dfrac{l_m}{b}}\right)}$

w specific weight of water, lb/cu ft

$C_\triangle$ load coefficient or beam loading, $\triangle/wb^3$

C_R resistance coefficient, R/wb^3

C_V speed coefficient or Froude number, $V/\sqrt{gb}$

C_f skin-friction drag coefficient,

$$\frac{F}{\frac{\rho}{2} S_f V_m^2} = \frac{\cos \beta \cos^2 \tau}{\frac{l_m}{b} \cos \tau - C_{L_b}} \left(C_{D_b} - C_{L_b} \tan \tau\right)$$

C_{L_b} lift coefficient based on beam, $\dfrac{\triangle}{\frac{\rho}{2} V^2 b^2} = 2 \dfrac{C_\triangle}{C_V^2}$

C_{D_b} drag coefficient based on beam, $\dfrac{R}{\frac{\rho}{2} V^2 b^2}$

C_{L_S} lift coefficient based on principal wetted area,

$$\frac{\triangle}{\frac{\rho}{2} V^2 S} = \frac{C_{L_b}}{l_m/b}$$

C_{D_S} drag coefficient based on principal wetted area,

$$\frac{R}{\frac{\rho}{2} V^2 S} = \frac{C_{D_b}}{l_m/b}$$

β angle of dead rise, deg

ρ mass density of water, slugs/cu ft

τ trim (angle between keel and horizontal), deg

ν kinematic viscosity, ft^2/sec

DESCRIPTION OF MODEL

A sketch of the model and a cross section with the pertinent dimensions are shown in figure 1. The basic angle of dead rise is 40° and the flare is a circular arc tangent to the basic section and horizontal at the chine. The radius of the arc is such that the angle of dead rise, measured from the keel to chine, is 32° 47'. The resulting cross section is similar to that of the forebody used in the investigation of the effect of angle of dead rise on the hydrodynamic characteristics of a flying boat having a hull length-beam ratio of 15 as given in reference 2.

The model is constructed of brass, has a rectangular plan form, a beam of 4 inches, and is 36 inches long. The details of construction and finish of the model are the same as those described in reference 1.

APPARATUS AND PROCEDURE

The Langley tank no. 1, the apparatus for towing the model, and the instrumentation for measuring the lift, drag, and trimming moment are described in reference 3. A diagram of the model and towing gear is presented in figure 2. The basic schedule for the tests and the procedure used to obtain the data were generally the same as those described in reference 1. Wetted lengths and areas were determined from underwater photographs and from visual readings of the wetted length where photographs were not available. A typical underwater photograph is shown in figure 3.

Because of a failure of the capacity-bridge water-level recorder described in reference 1, draft measurements were not obtained during these tests. At the conclusion of the tests, however, a new recorder (shown in fig. 4) became available and a limited part of the schedule was repeated to obtain draft data for verification of pile-up at the keel. This water-level recorder consisted of a vertically oscillating prod with electrical pickups arranged so that the position of the prod was continuously recorded together with the instant of contact with the water. Uniform vertical motion of the prod was obtained with a motor and cam arrangement as shown in figure 4. The vertical position was recorded by means of a slide-wire pickup and Wheatstone bridge. From a calibration of the position of the prod relative to the undisturbed water surface, the actual water level at the instant of contact was determined. Visual draft readings and water-level measurements were taken simultaneously and changes in water level were applied as draft corrections.

The aerodynamic forces on the model and towing gate were held to a minimum by use of the windscreen described in reference 1. The residual windage tare was approximately 0.3 pound at a speed of 82 feet per second. The proper tares were deducted from the measured drags to obtain the hydrodynamic resistances. The tares for load and moment were negligible.

The quantities measured are generally believed to be accurate within the following limits:

Load, lb . . . . ±0.15
Resistance, lb . . . . ±0.15
Trimming moment, ft-lb . . . . ±0.50
Wetted length, in. . . . . ±0.25
Trim, deg . . . . ±0.10
Speed, ft/sec . . . . ±0.20

RESULTS AND DISCUSSION

The experimental data obtained for all conditions where the chines were wetted are presented in table I. Data for the dry-chine condition were omitted inasmuch as the precision of measurement became marginal because of small wetted areas.

In table I, the load, resistance, speed, wetted lengths, and center-of-pressure location are expressed in the form of conventional nondimensional hydrodynamic coefficients based on beam. The lift and drag coefficients are expressed in terms of the square of the beam and, also, in terms of the principal wetted area. Both forms of lift and drag coefficients are included because the former has been used extensively in the literature on planing and the latter is analogous to the fundamental coefficients for aerodynamic lifting elements.

Data for a planing surface having an angle of dead rise of 20° and horizontal chine flare are presented in reference 1 and are used for comparison throughout this report.

Wetted length.- The variation of mean-wetted-length—beam ratio l_m/b with lift coefficient C_{L_b} is shown in figure 5. The experimental data lie along a single curve for each trim and l_m/b is determined by the value of C_{L_b} rather than by the specific speed or load. The variations of l_m/b with C_{L_b} for the surface having a 20° angle of dead rise are also included in figure 5 (dashed lines) and show the same trends. For a given trim and C_{L_b}, the increase in angle of dead rise substantially increases the mean wetted length.

The relation between the chine-wetted-length—beam ratio l_c/b and the keel-wetted-length—beam ratio l_k/b is shown in figure 6. The difference $\dfrac{l_k - l_c}{b}$ is constant for a given trim as was found for the surface having an angle of dead rise of 20°. The variation of the difference between chine and keel wetted lengths with trim is shown in figure 7. The variation predicted by the wave-rise theory of Wagner, as applied in reference 4, is also shown. A mean angle of dead rise of 36.4° was assumed in order to account for the reduction in angle of dead rise caused by horizontal chine flare. Although the computed values are larger than the experimental values, the trends with trim are generally the same.

Center of pressure.- The nondimensional center-of-pressure location l_p/b is plotted against C_{L_b} in figure 8. The center-of-pressure location is defined as the distance from the trailing edge to the intersection of the resultant hydrodynamic force vector with the keel of the model. For a given trim, the data lie on a single curve, an indication that, for a given trim and lift coefficient, l_p/b is, for practical considerations, independent of speed and load. A comparison of these curves with the curves obtained for the surface having a 20° angle of dead rise (dashed lines in fig. 8) shows that an increase in angle of dead rise effects a significant forward shift of the center of pressure.

Figure 9 presents plots of l_p/b against l_m/b for each of the trims. The variation with trim of the ratio of the center-of-pressure location to the mean wetted length is presented in figure 10 and can be considered a constant equal to 0.62 up to 18° of trim. A slight decrease in this ratio occurs with further increase in trim. Figure 10 shows that this trend is similar to that found for the surface having an angle of dead rise of 20° and horizontal chine flare. The increase in angle of dead rise reduced the value of the constant from 0.67 to 0.62.

Draft.- Draft measurements are shown in figure 11 where the measured draft in beams is plotted against that computed from the keel wetted length. The computed draft is defined by $\dfrac{l_k}{b} \sin \tau$. These data are rather limited in scope and have been omitted from table I. Most of these data were obtained after the wind-screening configuration (ref. 1) had been removed and are presented in figure 11 primarily to verify the existence of pile-up of water at the keel. The data generally fall below the computed curves; this result strongly suggests a pile-up at high trims. This pile-up increases with increase in trim but to a lesser degree for the surface having a 40° angle of dead rise than for the surface having a basic angle of dead rise of 20°.

Buoyancy.- Some of the light-load low-speed conditions at the lower trims were influenced by buoyancy in that the data obtained for these conditions did not fit the curves for which C_{L_b} is the governing parameter. The tests of reference 1 in which the pattern of this deviation is defined were not made for this model. Inspection of the data presented herein, however, in light of the results of reference 1, indicated that the bulk of the conditions so affected were those for which buoyancy, based on the displaced volume, equaled at least 20 percent of the load.

For a given trim and C_{L_b}, the curves presented in figure 12 establish a minimum load below which the data will not fit the curves where C_{L_b} is the governing parameter. The area below each trim curve represents data that will be most influenced by buoyancy. Data falling in this range of speed and load have been omitted from table I and from the curves.

Resistance.- The variation of drag with lift is presented in figure 13 as a plot of C_{D_b} against C_{L_b}. The solid lines represent the total drag and are faired through the data. The dashed lines represent the induced drag coefficient, defined by C_{L_b} tan τ. The friction drag is then represented by the difference between the solid and dashed lines.

The friction drag for the surface having an angle of dead rise of 40° is greater than that for the surface having an angle of dead rise of 20°. This increase in friction with increased angle of dead rise can be attributed to the greater wetted area required to support a given load as evidenced by the greater l_m/b value for a given C_{L_b} (fig. 5). At trims of 24° and greater, friction is negligible and the total drag, for practical purposes, is equal to the induced drag Δ tan τ.

Skin-friction drag coefficients were calculated in the manner described in reference 1 for trims where friction is significant. The variation of skin-friction drag coefficient with Reynolds number is shown in figure 14 for trims of 4°, 6°, 12°, and 18°, together with the Schoenherr line for turbulent flow and the Blasius line for laminar flow. The grouping of the data indicates that at high Reynolds numbers the friction can be calculated, for engineering purposes, by use of the Schoenherr turbulent-flow equation (ref. 5).

CONCLUDING REMARKS

The results obtained from an experimental investigation of a planing surface having an angle of dead rise of 40° and horizontal

chine flare indicate that, during high-speed steady-state planing, the
important planing characteristics for a given trim depend principally on
lift coefficient. The variation of the difference between chine and keel
wetted lengths with trim angle has the same general trend as theory.
The ratio of center-of-pressure location forward of the trailing edge
to the mean wetted length, for most practical applications, is a constant
up to 18° of trim but decreases somewhat at higher trims. Increasing
the basic angle of dead rise of a horizontally flared surface from 20°
(NACA TN 2804) to 40° decreases this ratio from 0.67 to 0.62.

Evidence of pile-up of water at the keel was present at all times
and was substantial at high trims. The amount of pile-up was less for
the model tested than for the surface having a 20° angle of dead rise and
horizontal chine flare. For the surface having a 40° angle of dead rise,
the friction drag is appreciable over a wider range of trim than for the
surface having a 20° angle of dead rise because of the increased wetted
area required to support a given load. At trims of 24° and greater,
friction drag is negligible and the resistances for these trims may be
assumed equal to the load times the tangent of the trim angle.

Langley Aeronautical Laboratory,
        National Advisory Committee for Aeronautics,
                Langley Field, Va., September 23, 1952.

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TABLE I

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE

AND HORIZONTAL CHINE FLARE - LANGLEY TANK MODEL 277A

Average kinematic viscosity = 10.40×10^{-6} ft²/sec; specific weight of tank water = 63.4 lb/cu ft

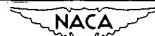| Trim, τ, deg	c_Δ	c_V	c_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	c_{L_b}	c_{D_b}	c_{L_S}	c_{D_S}
4	2.13	9.61	0.72	0.62	2.18	3.72	1.68	0.0458	0.0155	0.021	0.0071
4	4.26	10.43	1.46	2.85	4.36	5.88	2.55	.0785	.0266	.018	.0061
4	4.26	13.88	1.40	.62	2.18	3.72	1.66	.0436	.0146	.020	.0067
4	4.26	14.03	1.49	.56	2.11	3.65	1.73	.0422	.0152	.020	.0072
4	6.39	10.16	1.99	5.50	7.05	8.60	4.15	.1199	.0381	.017	.0054
4	6.39	10.16	2.06	5.75	7.31	8.85	4.28	.1243	.0395	.017	.0054
4	6.39	10.31	2.05	5.75	7.31	8.85	4.28	.1170	.0387	.016	.0053
4	6.39	12.69	2.01	2.62	4.18	5.72	2.79	.0794	.0251	.019	.0060
4	6.39	12.81	2.01	2.75	4.30	5.85	2.59	.0774	.0249	.018	.0057
4	6.39	12.81	2.05	2.75	4.30	5.85	2.61	.0774	.0245	.018	.0058
4	6.39	12.87	2.06	2.95	4.49	6.02	2.34	.0763	.0247	.017	.0055
4	6.39	16.78	2.11	.62	2.18	3.72	1.76	.0458	.0150	.021	.0069
4	6.39	16.78	2.16	.62	2.18	3.72	1.50	.0458	.0153	.021	.0070
4	6.39	16.87	2.16	.88	2.40	3.92	.85	.0456	.0151	.019	.0063
4	6.39	17.23	2.17	.62	2.18	3.72	1.50	.0436	.0146	.020	.0067
4	6.39	19.98	2.41	.42	2.02	3.60	1.05	.0323	.0121	.016	.0060
4	6.39	21.78	2.58	0	1.55	3.10	1.44	.0264	.0109	.017	.0070
4	10.65	16.35	3.39	2.88	4.43	5.98	2.80	.0797	.0253	.018	.0057
4	10.65	16.41	3.33	2.75	4.30	5.85	2.54	.0774	.0245	.018	.0057
4	10.65	16.41	3.45	3.00	4.56	6.12	2.70	.0775	.0255	.017	.0056
4	10.65	21.65	3.49	.75	2.30	3.85	1.30	.0460	.0147	.020	.0064
4	10.65	22.32	3.44	.50	2.05	3.60	1.28	.0430	.0137	.021	.0067
4	10.65	25.01	3.71	.25	1.80	3.35	1.03	.0342	.0119	.019	.0066
4	19.17	21.81	5.78	2.88	4.43	5.98	2.66	.0797	.0244	.018	.0055
4	19.17	21.81	5.84	3.00	4.55	6.10	2.68	.0819	.0246	.018	.0054
4	19.17	21.81	5.84	2.88	4.43	5.98	2.68	.0797	.0244	.018	.0055
4	19.17	22.11	5.95	3.50	4.88	6.25	2.69	.0781	.0244	.016	.0050
4	19.17	25.01	5.74	1.62	3.18	4.72	1.88	.0604	.0184	.019	.0058
6	.85	6.19	.23	.08	1.03	1.98	---	.0443	.0123	.043	.0119
6	2.13	6.74	.58	1.50	2.45	3.40	1.38	.0931	.0255	.038	.0104
6	2.13	9.73	.64	.15	1.10	2.05	.51	.0451	.0136	.041	.0124
6	6.39	10.16	1.63	2.50	3.46	4.40	2.13	.1246	.0315	.036	.0091
6	6.39	12.90	1.61	.88	1.83	2.78	1.02	.0769	.0194	.042	.0106
6	6.39	17.08	1.79	---	---	---	.66	---	---	---	---
6	6.39	21.29	2.03	0	1.04	2.08	.72	.0281	.0088	.027	.0085
6	10.65	10.95	2.60	4.50	5.45	6.40	3.36	.1744	.0431	.032	.0079
6	10.65	16.29	2.61	.88	1.83	2.78	1.11	.0805	.0196	.044	.0107
6	10.65	21.84	2.96	.08	1.03	1.98	.72	.0443	.0124	.043	.0120
6	19.17	13.75	4.74	6.00	6.96	7.90	4.44	.2018	.0501	.029	.0072
6	19.17	14.70	4.55	4.80	5.77	6.72	3.63	.1789	.0421	.031	.0073
6	19.17	17.69	4.40	2.55	3.55	4.55	2.22	.1207	.0280	.034	.0079
6	19.17	21.93	4.18	.92	1.99	3.05	1.08	.0796	.0173	.040	.0087
6	19.17	25.16	4.63	.50	1.45	2.40	.81	.0609	.0145	.042	.0100
6	27.69	17.69	6.53	4.85	5.80	6.72	3.60	.1740	.0418	.030	.0072
6	27.69	21.11	6.30	2.55	3.54	4.52	2.28	.1239	.0283	.035	.0080
6	27.69	24.92	6.31	1.20	2.15	3.10	1.29	.0882	.0202	.041	.0094
6	27.69	25.32	5.86	1.28	2.28	3.28	1.32	.0866	.0182	.038	.0080
6	36.21	17.35	8.68	7.25	8.10	8.95	5.10	.2430	.0575	.030	.0071
6	36.21	19.92	8.61	4.92	5.86	6.78	3.69	.1817	.0434	.031	.0074
6	36.21	24.40	8.31	3.05	3.97	4.88	2.19	.1231	.0278	.031	.0070
6	36.21	25.22	8.16	2.62	3.54	4.45	1.95	.1133	.0255	.032	.0072
6	53.25	24.34	12.42	4.72	5.65	6.58	3.60	.1808	.0418	.032	.0074
6	53.25	25.13	12.35	4.50	5.42	6.32	3.36	.1680	.0390	.031	.0072
12	.85	4.61	.24	.25	.68	1.10	---	.0802	.0229	.118	.0337
12	2.13	4.18	.53	1.50	1.93	2.35	---	.2432	.0602	.126	.0312
12	2.13	4.85	.54	.98	1.40	1.82	---	.1792	.0452	.128	.0323
12	2.13	7.29	.61	.15	.63	1.10	---	.0800	.0228	.127	.0362
12	6.39	10.10	1.75	.48	.90	1.32	.63	.1242	.0339	.138	.0377
12	6.39	12.72	1.73	.12	.55	.98	.33	.0787	.0213	.143	.0388
12	6.39	12.81	1.74	.15	.65	1.15	.29	.0780	.0212	.120	.0326
12	10.65	9.36	2.76	1.75	2.18	2.60	1.41	.2420	.0628	.111	.0288
12	10.65	10.86	2.81	1.00	1.42	1.85	.87	.1803	.0476	.127	.0335
12	10.65	16.44	2.99	.10	.61	1.12	.39	.0781	.0220	.128	.0361
12	19.17	8.78	5.04	5.12	5.55	5.98	3.51	.4940	.1304	.089	.0235
12	19.17	9.76	4.91	4.00	4.43	4.85	2.69	.3987	.1028	.090	.0232
12	19.17	9.76	5.00	3.92	4.39	4.85	2.85	.3995	.1040	.091	.0237
12	19.17	12.47	4.78	1.88	2.31	2.75	1.41	.2449	.0612	.106	.0265
12	19.17	12.50	4.89	1.70	2.19	2.68	1.41	.2453	.0624	.112	.0285

NACA

TABLE I - Continued

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE

AND HORIZONTAL CHINE FLARE - LANGLEY TANK MODEL 277A

Trim, τ, deg	c_Δ	c_V	c_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	C_{L_b}	C_{D_b}	C_{L_S}	C_{D_S}
12	19.17	17.63	4.78	0.50	1.00	1.50	0.49	0.1230	0.0307	0.123	0.0307
12	19.17	17.63	4.89	.40	.95	1.50	.54	.1226	.0313	.129	.0329
12	19.17	22.11	4.90	.08	.60	1.12	.33	.0780	.0199	.130	.0332
12	19.17	25.16	5.40	0	.42	.85	.36	.0596	.0168	.142	.0401
12	27.69	15.16	7.14	1.72	2.19	2.65	1.50	.2409	.0620	.110	.0283
12	27.69	17.78	7.08	.92	1.40	1.88	.93	.1736	.0445	.124	.0318
12	27.69	20.89	7.19	.38	.87	1.38	.60	.1262	.0327	.145	.0376
12	27.69	25.19	7.34	.20	.73	1.25	.30	.0869	.0231	.119	.0316
12	36.21	11.99	9.57	5.32	5.73	6.12	3.69	.5042	.1324	.088	.0231
12	36.21	12.50	9.46	4.82	5.23	5.62	3.26	.4602	.1203	.088	.0230
12	36.21	13.42	9.44	3.92	4.38	4.82	2.82	.3986	.1042	.091	.0238
12	36.21	15.16	9.33	2.72	3.17	3.60	2.13	.3138	.0808	.099	.0255
12	36.21	20.22	9.07	1.00	1.48	1.95	.86	.1761	.0443	.119	.0299
12	36.21	24.25	9.33	.40	.90	1.40	.60	.1224	.0316	.136	.0351
12	36.21	24.95	9.52	.40	.91	1.42	.54	.1156	.0305	.127	.0335
12	53.25	14.64	14.16	5.20	5.61	6.00	3.60	.4937	.1318	.088	.0235
12	53.25	16.38	13.86	3.82	4.28	4.72	2.76	.3938	.1031	.092	.0241
12	53.25	20.89	13.47	1.72	2.18	2.62	1.44	.2442	.0615	.112	.0282
12	53.25	24.52	13.52	.95	1.44	1.92	.93	.1757	.0448	.122	.0311
12	70.29	17.17	18.57	4.92	5.35	5.75	3.45	.4762	.1257	.089	.0235
12	70.29	21.11	18.00	2.68	3.11	3.55	2.04	.3141	.0802	.101	.0258
12	70.29	24.16	17.85	1.70	2.19	2.68	1.41	.2409	.0611	.110	.0279
12	70.29	25.16	17.60	1.55	1.90	2.25	1.26	.2204	.0555	.116	.0292
12	87.33	18.36	23.24	5.20	5.63	6.05	3.57	.5180	.1374	.092	.0244
12	87.33	23.58	22.11	2.80	3.24	3.68	2.01	.3143	.0794	.097	.0245
12	87.33	25.01	22.34	2.20	2.63	3.05	1.68	.2788	.0713	.106	.0271
18	.85	4.58	.26	0	.28	.55	.39	.0812	.0248	.290	.0885
18	2.13	4.12	.79	1.00	1.28	1.55	.91	.2509	.0933	.196	.0729
18	2.13	4.82	.79	.62	.90	1.18	.63	.1818	.0678	.202	.0753
18	6.39	10.10	2.26	.17	.53	.88	.44	.1267	.0448	.239	.0846
18	6.39	10.13	2.30	.25	.52	.80	.57	.1238	.0445	.238	.0856
18	10.65	9.30	3.73	.88	1.15	1.42	.78	.2461	.0861	.214	.0749
18	10.65	10.89	3.70	.55	.81	1.07	.56	.1774	.0617	.219	.0762
18	10.65	10.89	3.76	.55	.81	1.08	.63	.1774	.0627	.219	.0774
18	19.17	9.09	6.72	2.25	2.53	2.80	1.65	.4630	.1622	.183	.0641
18	19.17	12.47	6.64	.80	1.10	1.40	.64	.2464	.0854	.224	.0776
18	19.17	12.50	6.77	.85	1.11	1.38	.69	.2442	.0860	.220	.0775
18	19.17	12.57	6.69	.88	1.11	1.35	.68	.2409	.0841	.217	.0758
18	19.17	17.60	6.79	.18	.50	.82	.30	.1220	.0433	.244	.0866
18	19.17	22.51	7.09	0	.28	.55	.27	.0767	.0284	.274	.1015
18	27.69	15.04	9.67	.88	1.15	1.42	.66	.2438	.0850	.212	.0739
18	27.69	15.25	---	.80	1.06	1.32	---	.2364	---	.223	---
18	27.69	17.63	9.57	.48	.76	1.05	.42	.1763	.0610	.232	.0802
18	27.69	21.62	9.42	.22	.55	.88	.27	.1177	.0402	.214	.0730
18	27.69	21.78	9.66	.02	.54	.90	.30	.1161	.0406	.215	.0751
18	27.69	25.53	9.87	.08	.44	.80	.24	.0845	.0301	.192	.0685
18	36.21	12.14	12.61	2.38	2.63	2.88	1.80	.4891	.1704	.186	.0648
18	36.21	15.25	12.58	1.25	1.53	1.80	.96	.3106	.1079	.203	.0705
18	36.21	17.48	12.57	.82	1.07	1.32	.66	.2354	.0817	.220	.0746
18	36.21	20.22	12.52	.48	.76	1.05	.45	.1748	.0605	.230	.0796
18	36.21	24.40	12.58	.25	.54	.82	.36	.1210	.0421	.224	.0779
18	36.21	25.41	12.74	.20	.51	.82	.30	.1107	.0390	.217	.0765
18	53.25	14.76	18.49	2.40	2.65	2.90	1.77	.4850	.1685	.183	.0636
18	53.25	16.29	18.51	1.88	2.10	2.32	1.38	.3990	.1386	.190	.0660
18	53.25	21.04	18.49	.82	1.09	1.35	.69	.2398	.0833	.220	.0764
18	53.25	24.49	18.45	.50	.79	1.08	.48	.1762	.0611	.223	.0774
18	70.29	17.08	24.37	2.45	2.69	2.92	1.71	.4788	.1662	.178	.0618
18	70.29	21.04	24.19	1.25	1.51	1.78	.93	.3156	.1086	.209	.0719
18	70.29	24.19	24.32	.80	1.06	1.32	.60	.2385	.0827	.225	.0780
18	87.33	18.76	30.40	2.42	2.68	2.92	1.71	.4931	.1721	.184	.0642
18	87.33	23.42	30.05	1.35	1.61	1.87	1.03	.3172	.1090	.197	.0677
24	2.13	2.99	.93	1.48	1.66	1.82	1.17	.4748	.2068	.286	.1246
24	2.13	4.27	.96	.62	.80	.98	.42	.2328	.1051	.291	.1314
24	2.13	4.94	.97	.38	.55	.72	.15	.1738	.0794	.316	.1443
24	6.39	10.25	2.95	.15	.36	.58	.36	.1210	.0559	.336	.1552
24	10.65	9.42	4.90	.55	.71	.88	.57	.2386	.1098	.336	.1547
24	10.65	10.89	4.98	.38	.57	.75	.12	.1796	.0841	.315	.1475
24	10.65	16.35	5.08	0	.25	.50	.21	.0788	.0376	.315	.1503
24	19.17	8.78	8.86	1.62	1.80	1.98	1.14	.4932	.2282	.274	.1268
24	19.17	9.82	8.85	1.20	1.38	1.55	.96	.3961	.1826	.287	.1323
24	19.17	12.47	8.65	.62	.80	.98	.48	.2448	.1106	.306	.1382
24	19.17	12.66	8.84	.52	.71	.90	.45	.2386	.1099	.336	.1548

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TABLE I - Concluded

EXPERIMENTAL DATA OBTAINED FOR A PLANING SURFACE HAVING A 40° ANGLE OF DEAD RISE

AND HORIZONTAL CHINE FLARE - LANGLEY TANK MODEL 277A

Trim, τ, deg	c_Δ	c_V	c_R	$\frac{l_c}{b}$	$\frac{l_m}{b}$	$\frac{l_k}{b}$	$\frac{l_p}{b}$	c_{L_b}	c_{D_b}	c_{L_S}	c_{D_S}
24	19.17	17.84	8.84	0.10	0.34	0.58	0.12	0.1197	0.0551	0.352	0.1622
24	27.69	15.16	12.68	.55	.71	.88	.44	.2407	.1101	.339	.1550
24	27.69	17.60	12.75	.32	.51	.70	.30	.1765	.0811	.346	.1591
24	27.69	21.35	12.85	.10	.34	.58	.21	.1200	.0557	.353	.1639
24	27.69	25.32	12.77	0	.25	.50	.09	.0855	.0395	.342	.1578
24	36.21	12.11	16.63	1.62	1.80	1.98	1.02	.4914	.2259	.273	.1255
24	36.21	15.19	16.39	.80	.96	1.12	.57	.3110	.1409	.324	.1468
24	36.21	24.19	16.95	.12	.34	.55	.20	.1224	.0573	.360	.1686
24	53.25	14.73	24.23	1.58	1.76	1.95	1.01	.4875	.2219	.277	.1261
24	53.25	16.16	24.25	1.18	1.36	1.55	.82	.4012	.1826	.295	.1343
24	53.25	20.89	24.18	.70	.87	1.05	.45	.2419	.1100	.278	.1264
24	53.25	24.49	24.13	.35	.54	.72	.30	.1798	.0816	.333	.1511
24	53.25	24.55	24.18	.38	.56	.75	.30	.1764	.0800	.315	.1429
24	53.25	25.35	---	.25	.48	.70	---	.1661	---	.346	---
24	70.29	16.99	32.08	1.58	1.73	1.88	1.08	.4861	.2216	.281	.1281
24	70.29	21.14	32.18	.80	.96	1.12	.59	.3120	.1430	.325	.1490
24	70.29	24.19	32.22	.58	.74	.90	.42	.2398	.1100	.324	.1486
24	70.29	25.22	32.47	.42	.62	.82	.36	.2182	.1008	.352	.1625
30	.85	4.67	.48	0	.12	.25	---	.0740	.0419	.617	.3488
30	2.13	4.18	1.19	.48	.60	.72	.37	.2460	.1377	.410	.2295
30	2.13	4.88	1.24	.28	.40	.53	.25	.1784	.1039	.446	.2598
30	2.13	7.38	1.25	0	.22	.42	---	.0792	.0464	.360	.2108
30	6.39	10.22	3.77	.12	.32	.50	.23	.1235	.0731	.386	.2284
30	6.39	12.78	3.82	0	.22	.42	.15	.0794	.0474	.361	.2154
30	10.65	9.30	6.21	.55	.67	.80	.42	.2466	.1438	.368	.2146
30	10.65	9.36	6.33	.50	.62	.75	.53	.2387	.1417	.385	.2286
30	10.65	10.80	6.27	.30	.44	.58	.27	.1817	.1069	.413	.2429
30	10.65	10.83	6.23	.30	.42	.55	.30	.1798	.1052	.428	.2505
30	10.65	16.32	6.24	0	.22	.45	.15	.0779	.0456	.354	.2072
30	10.65	16.38	6.43	0	.12	.25	---	.0752	.0454	.627	.3784
30	19.17	8.78	11.28	1.32	1.45	1.58	.78	.4944	.2907	.341	.2005
30	19.17	8.84	11.26	1.25	1.38	1.50	.94	.4885	.2872	.354	.2081
30	19.17	9.73	11.34	1.05	1.18	1.25	.60	.4059	.2397	.344	.2031
30	19.17	12.44	11.17	.50	.62	.75	.28	.2449	.1426	.395	.2300
30	19.17	14.24	11.37	.32	.45	.58	.21	.1877	.1112	.417	.2471
30	19.17	17.23	11.42	.20	.33	.45	.09	.1304	.0776	.395	.2351
30	19.17	21.75	11.29	0	.12	.25	.03	.0768	.0453	.640	.3771
30	27.69	10.37	16.37	1.32	1.43	1.52	.87	.5105	.3019	.357	.2111
30	27.69	12.44	16.37	.88	.96	1.05	.54	.3542	.2097	.369	.2184
30	27.69	14.88	16.41	.55	.68	.80	.36	.2496	.1480	.367	.2177
30	27.69	17.38	16.34	.38	.50	.62	.27	.1835	.1084	.367	.2167
30	27.69	21.11	16.22	.12	.25	.38	.15	.1230	.0721	.492	.2884
30	27.69	21.26	16.53	.18	.30	.42	.19	.1233	.0737	.411	.2456
30	27.69	25.10	16.45	0	.12	.25	.12	.0833	.0495	.694	.4126
30	36.21	15.04	21.45	.75	.85	.95	.48	.3171	.1878	.373	.2209
30	36.21	17.42	20.65	.50	.62	.75	.21	.2375	.1354	.383	.2184
30	36.21	20.44	20.65	.30	.42	.55	.06	.1718	.0979	.409	.2330
30	36.21	24.40	20.44	.18	.35	.52	.10	.1204	.0680	.344	.1943

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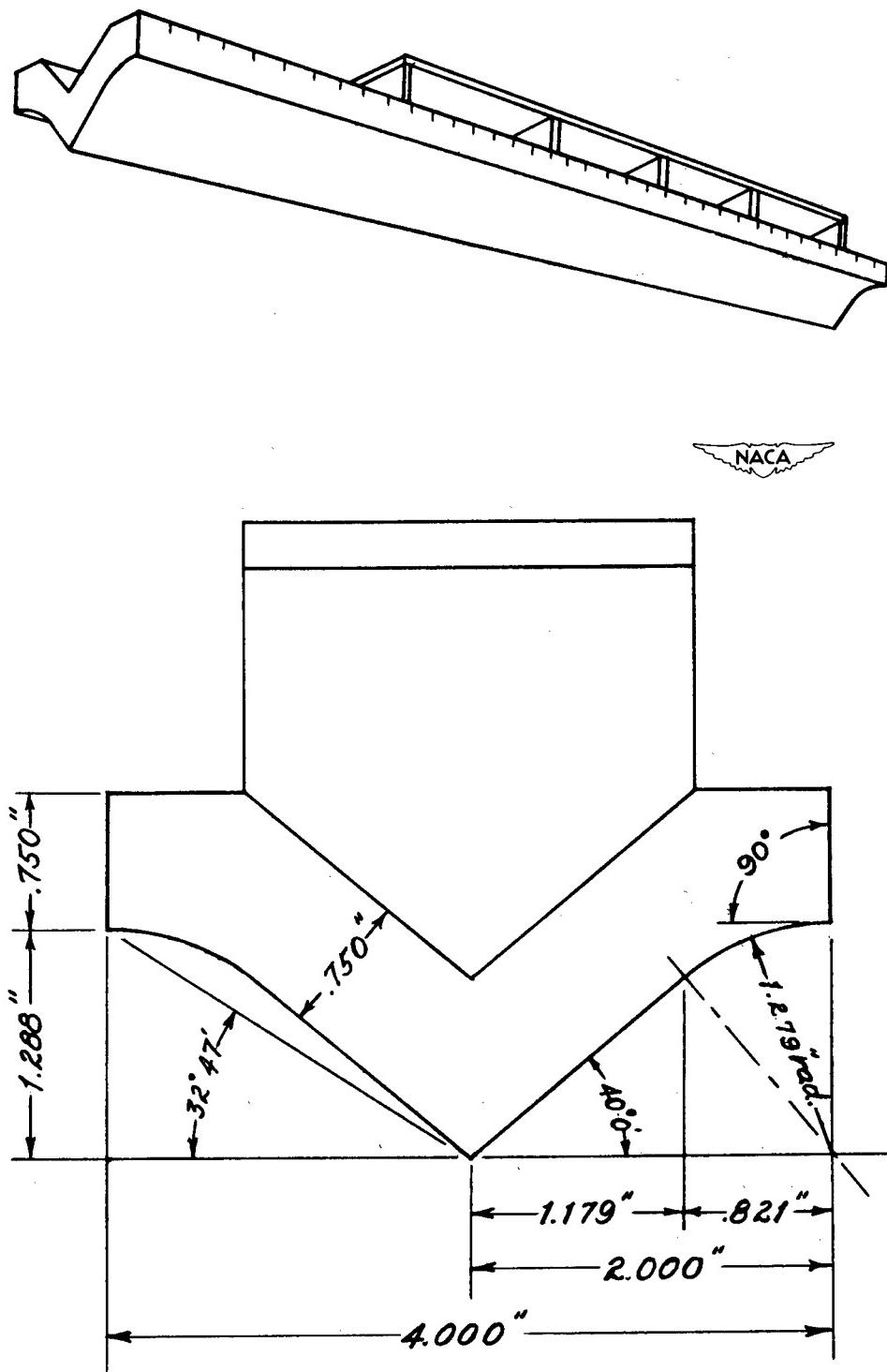
Figure 1.- Sketch and cross section of Langley tank model 277A.
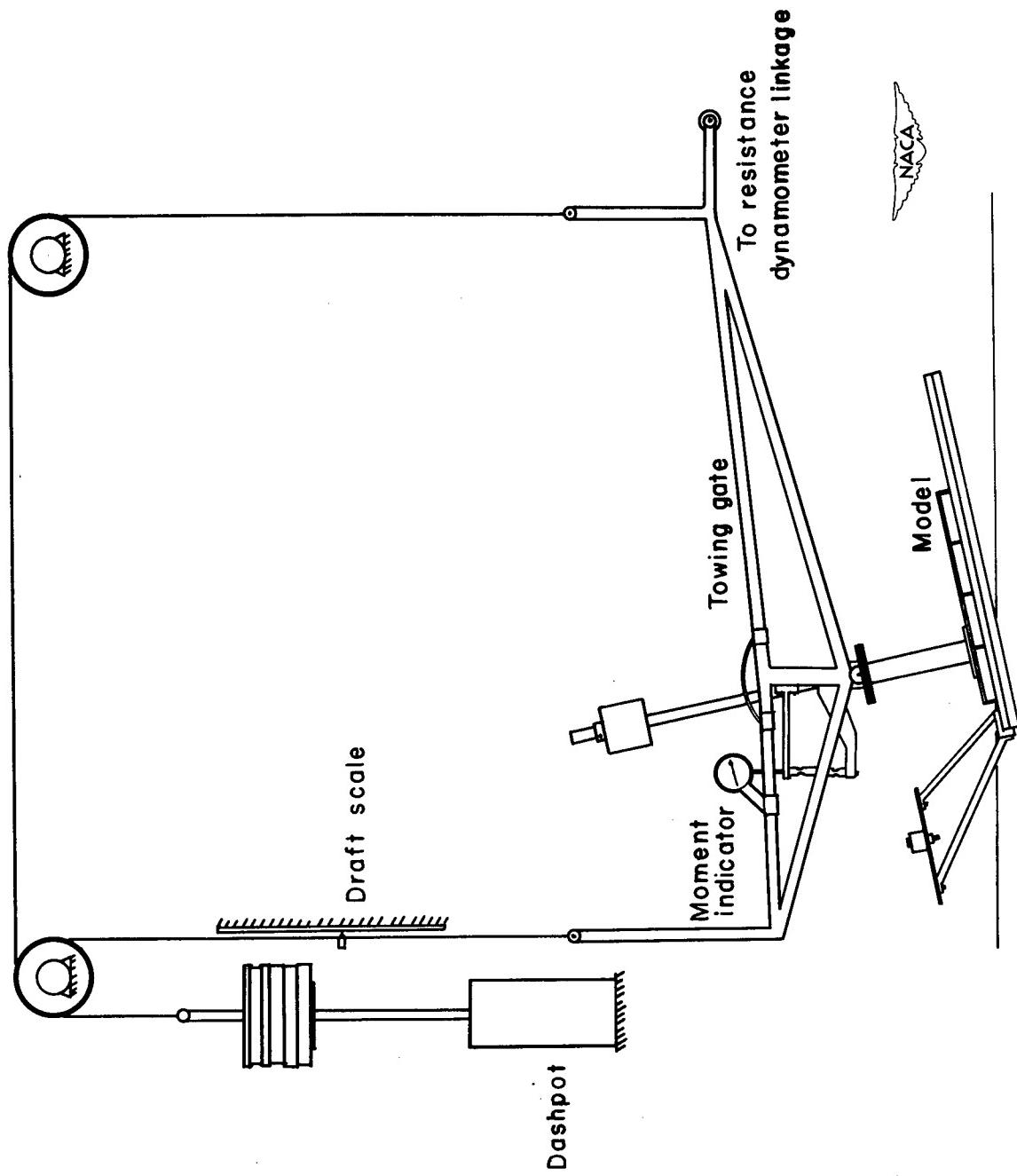
Figure 2.— Setup of model and towing gear.
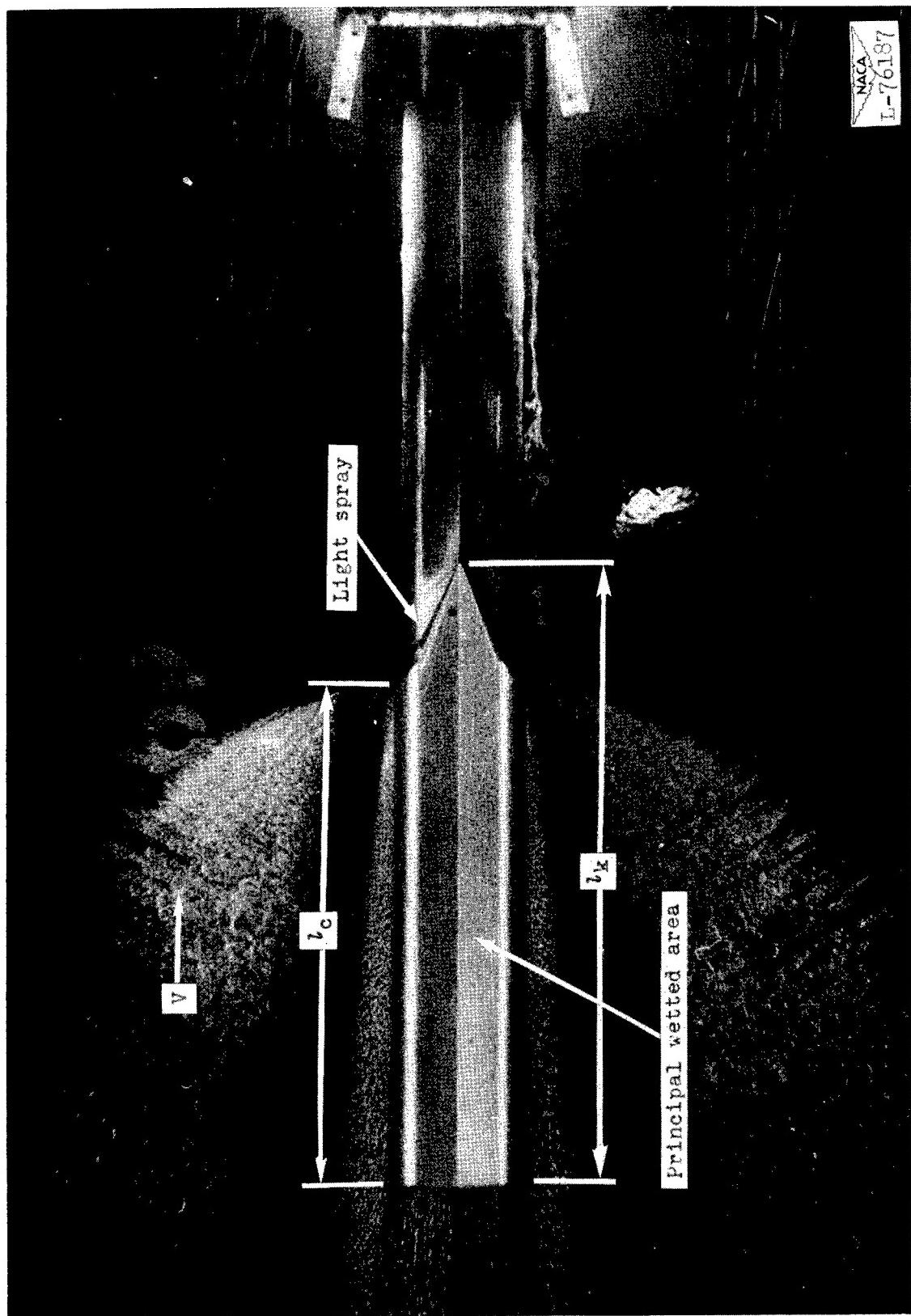
Figure 3.- Typical underwater photograph.
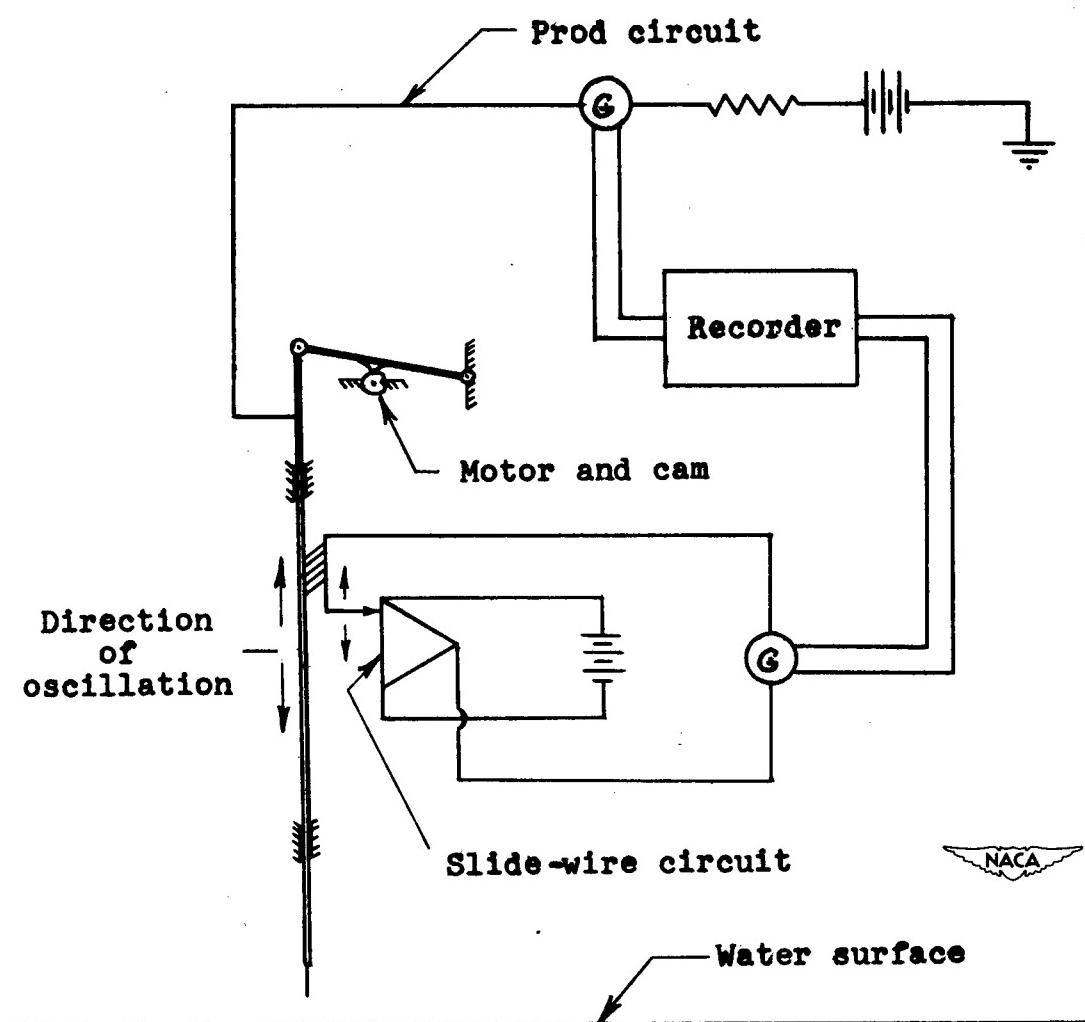
Figure 4.- Schematic drawing of water-level recorder.
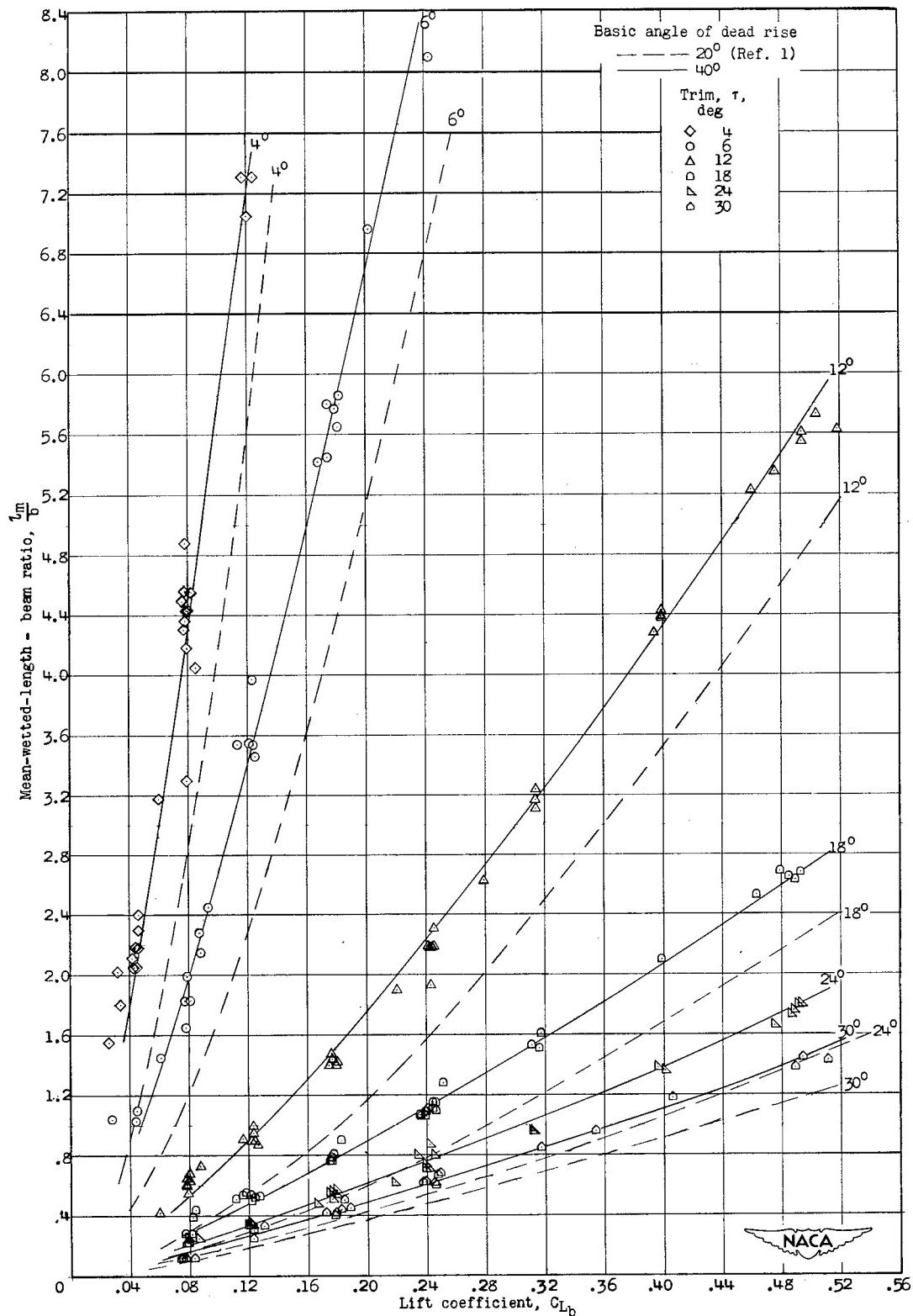
Figure 5.- Variation of mean-wetted-length—beam ratio with lift coefficient.
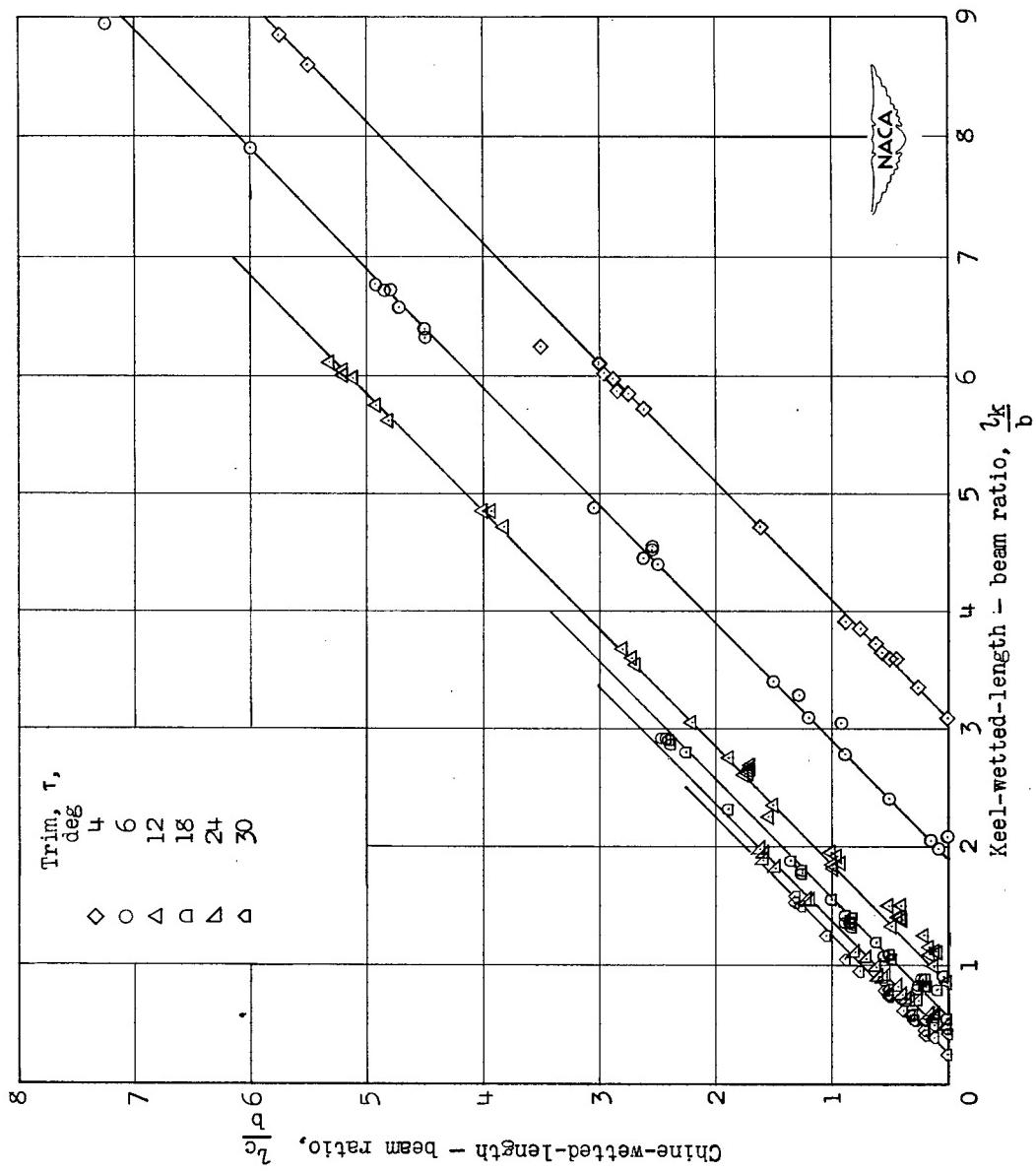
Figure 6.- Variation of chine-wetted-length—beam ratio with keel—wetted-length—beam ratio.
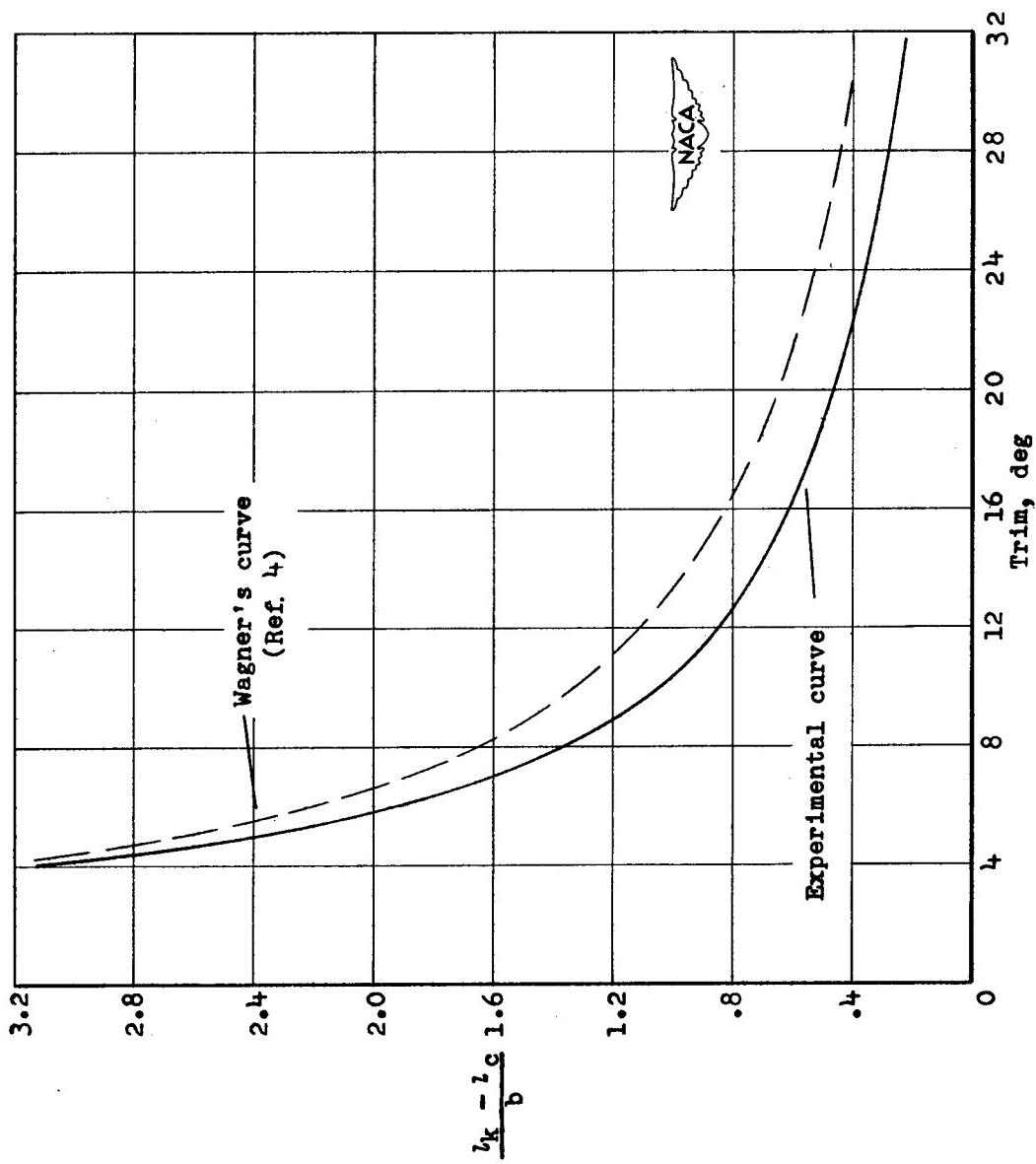
Figure 7.- Variation of $\dfrac{l_K - l_C}{b}$ with trim.
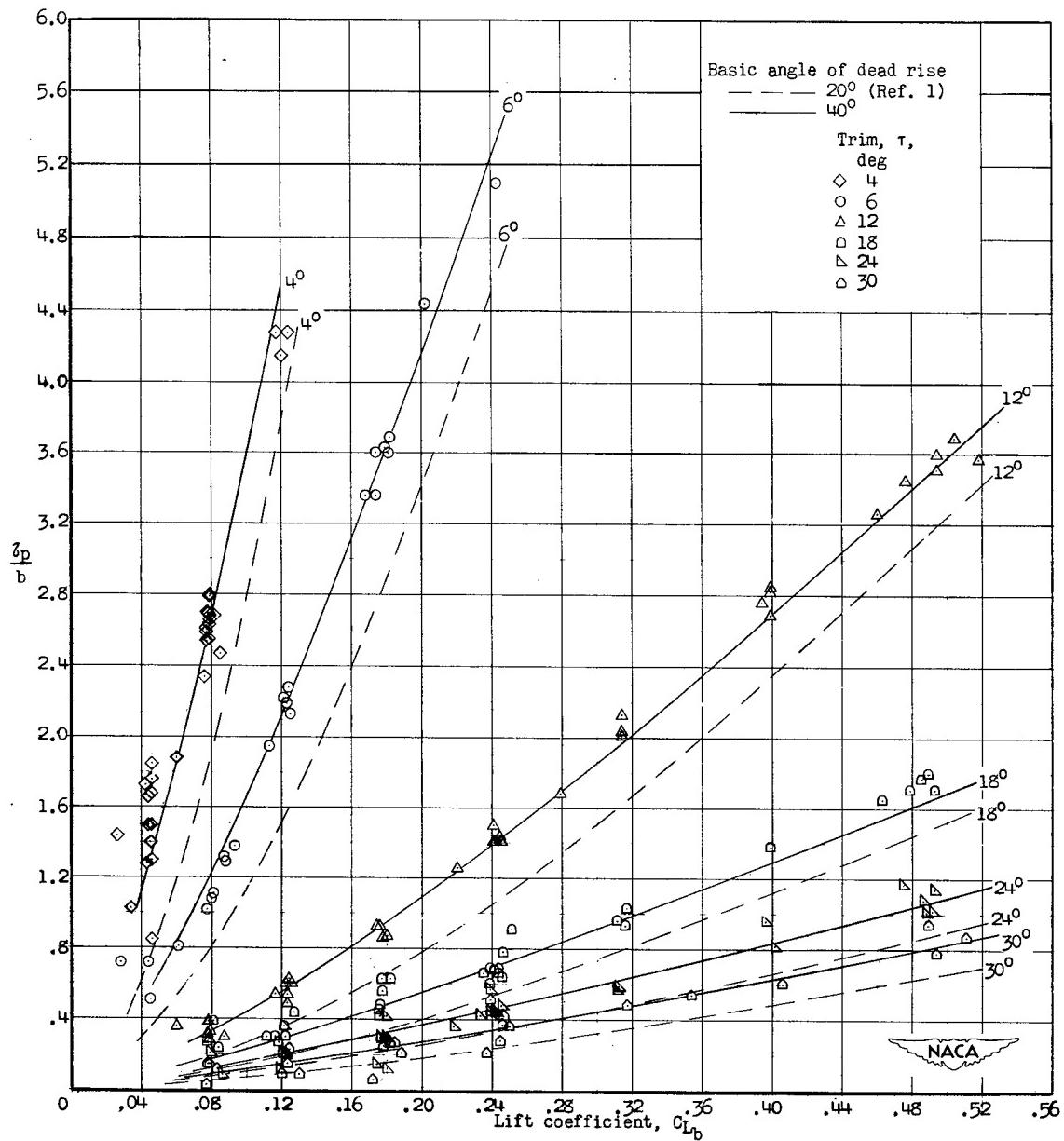
Figure 8.- Variation of nondimensional center-of-pressure location with
lift coefficient.

(a) Trim, 4°.

(b) Trim, 6°.

(c) Trim, 12°.

(d) Trim, 18°.

(e) Trim, 24°.

(f) Trim, 30°.
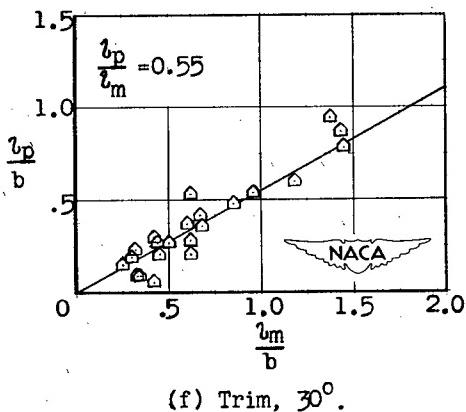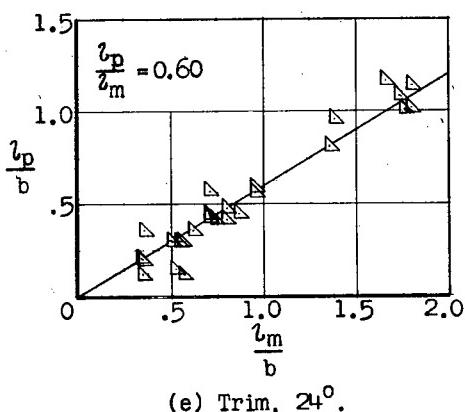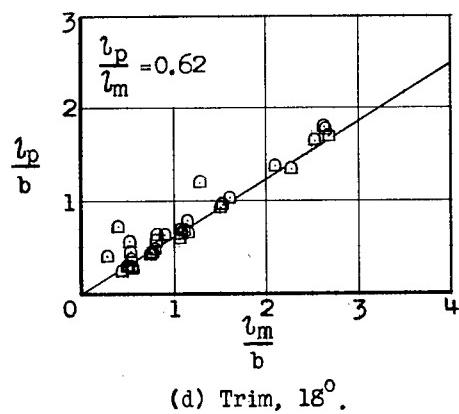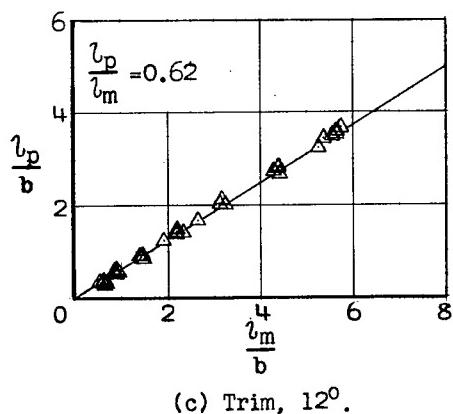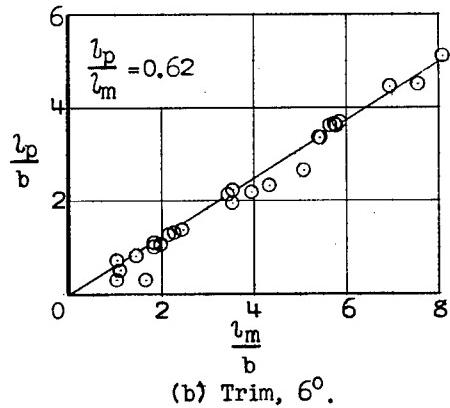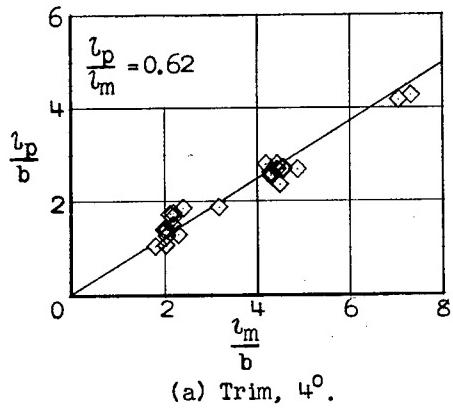
Figure 9.- Variation of l_p/b with l_m/b.
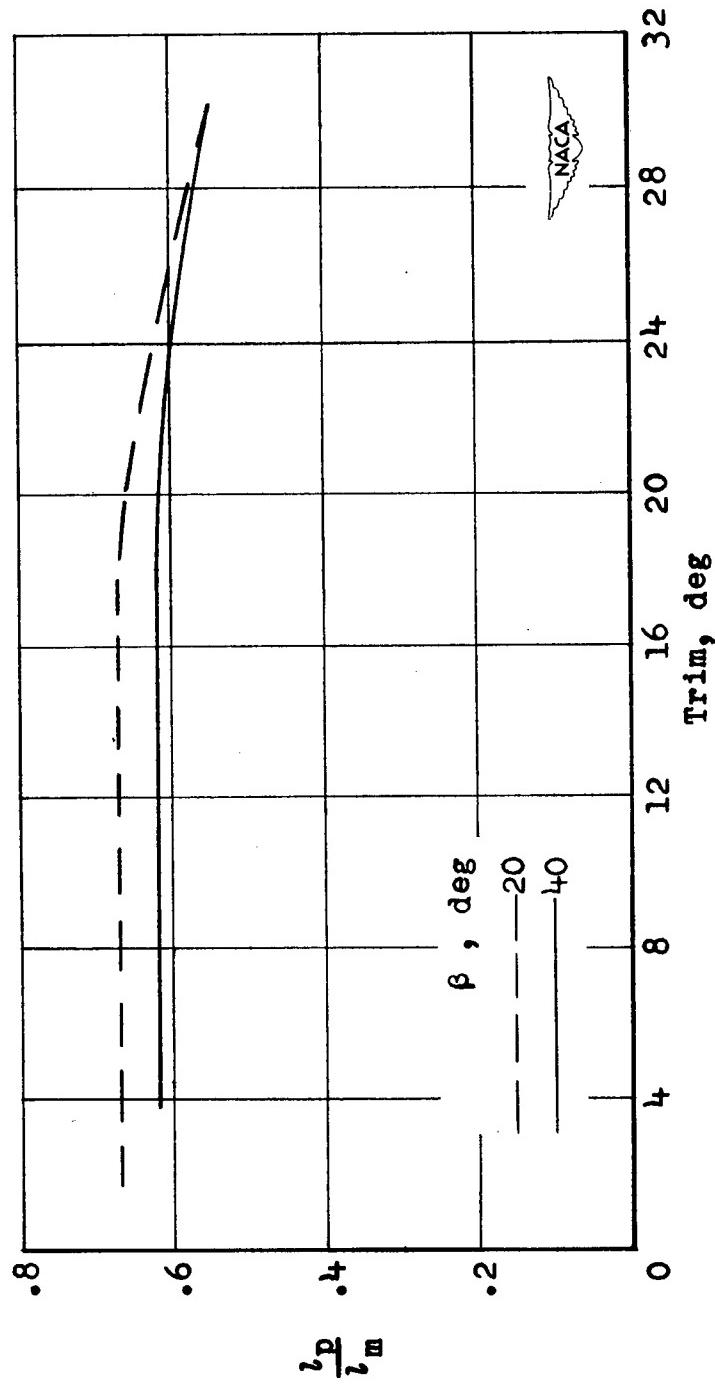
Figure 10.- Comparison of variation of l_p/l_m with trim for 20° (ref. 1) and 40° basic angles of dead rise.
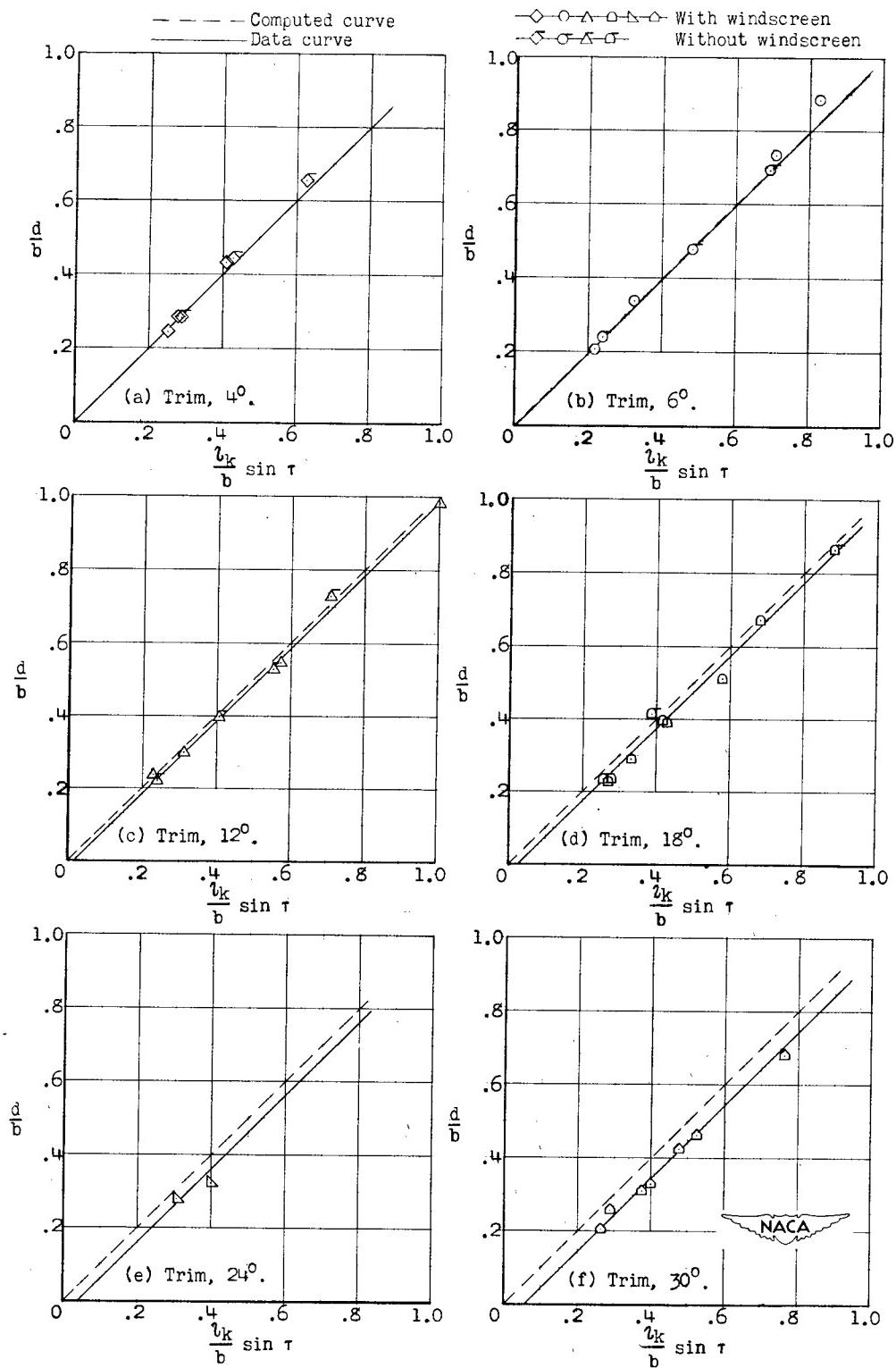
Figure 11.- Comparison of experimental draft data with computed draft
data showing pile-up at the keel.
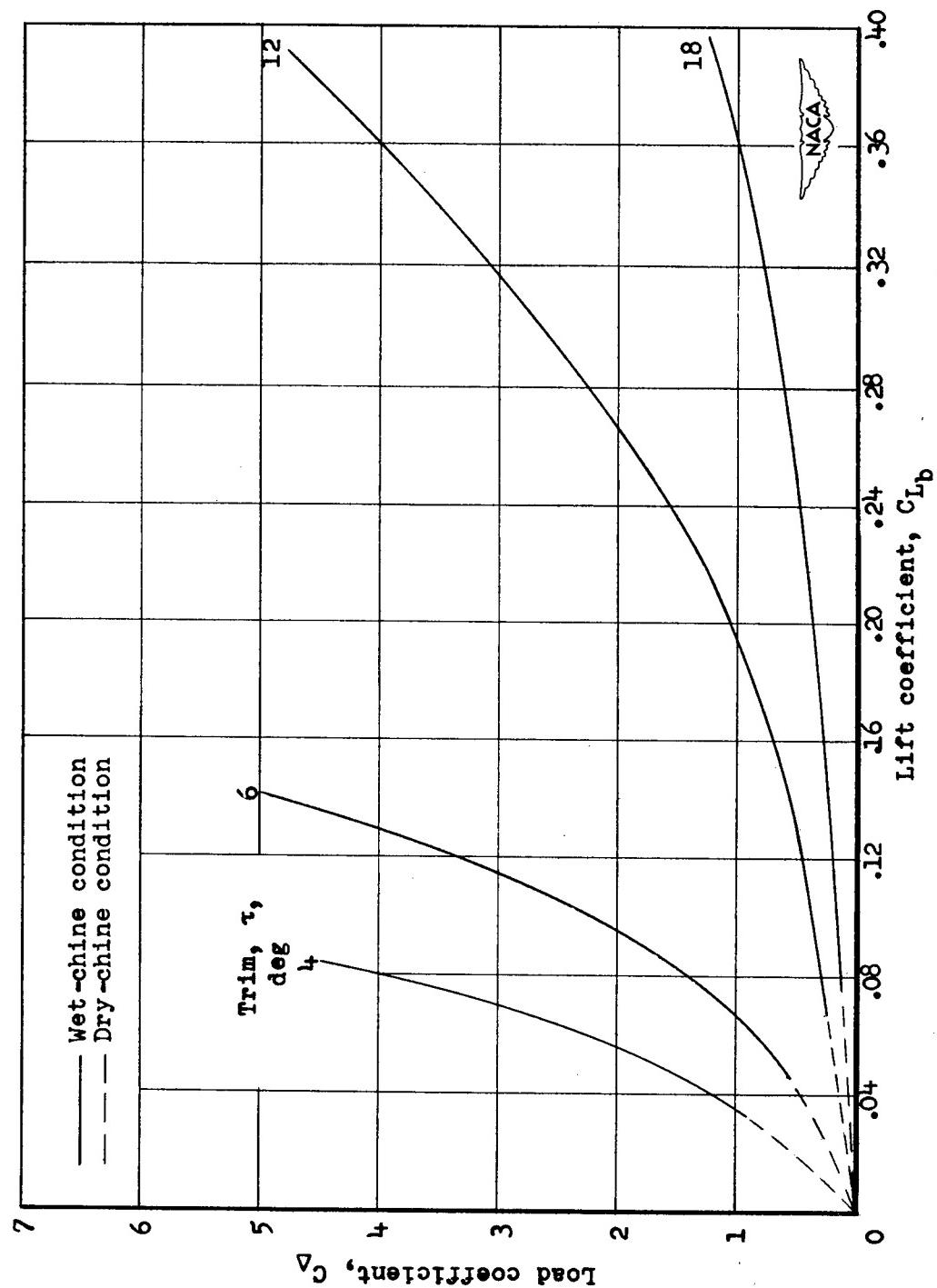
Figure 12.- Variation of minimum C_Δ for pure planing, based on 20-percent buoyancy.

(a) Trim, 4° and 6°.

(b) Trim, 12°, 18°, 24°, and 30°.
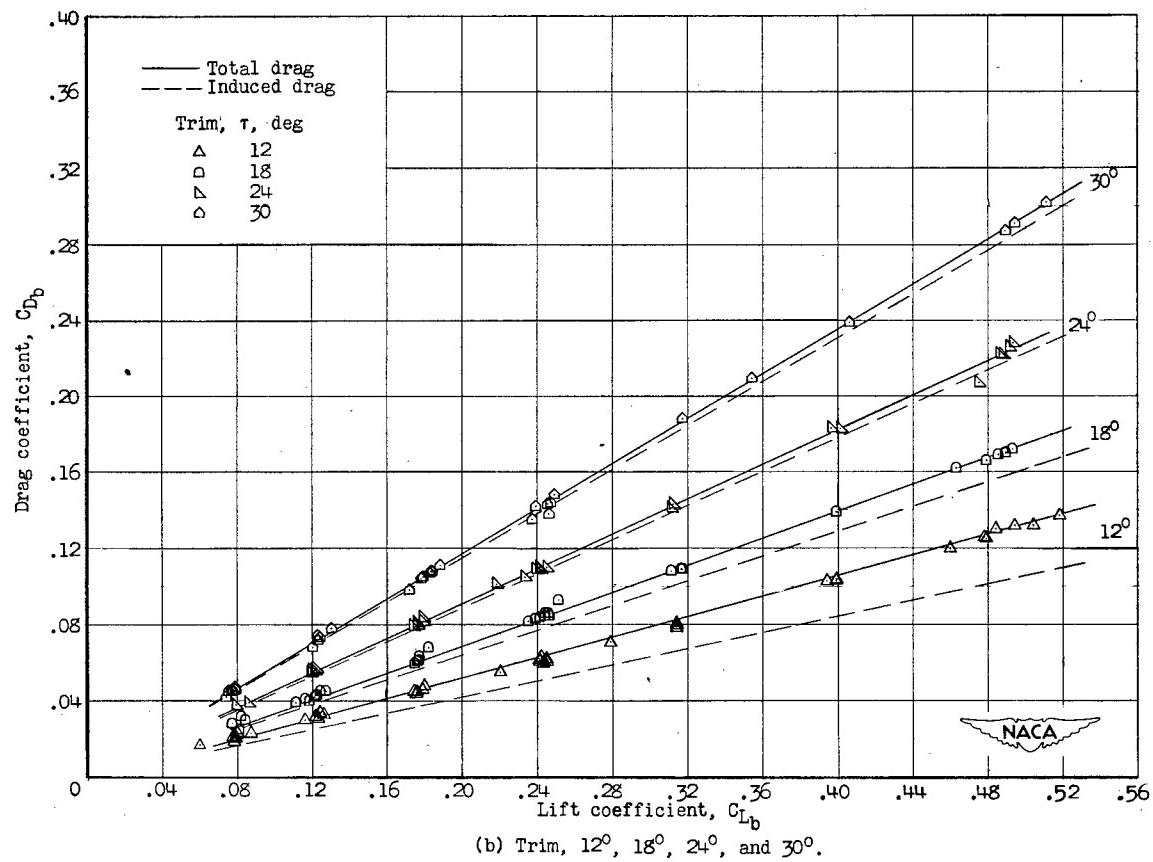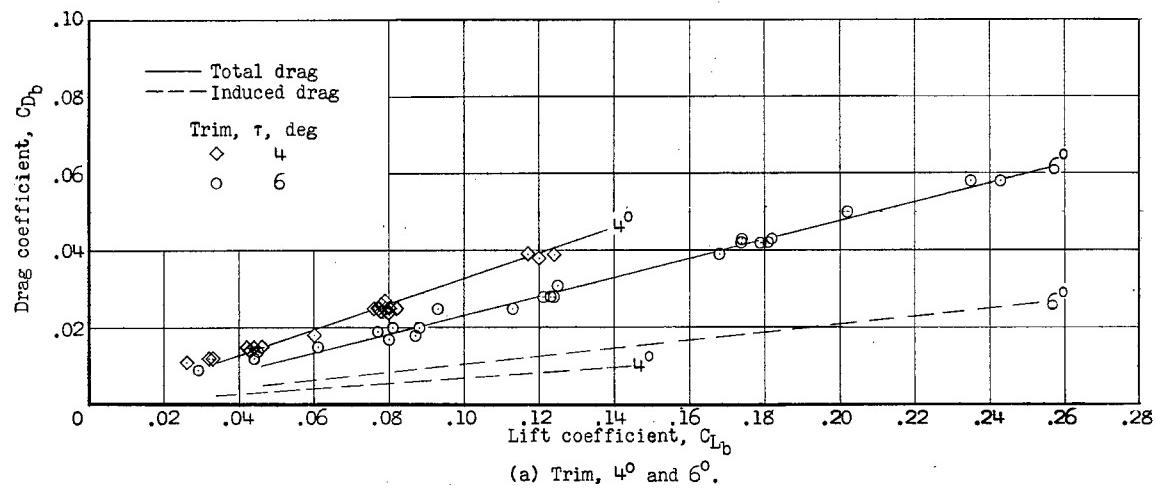
Figure 13.- Variation of drag coefficient with lift coefficient.

$$\text{Schoenherr, } \frac{0.242}{\sqrt{C_f}} = \log_{10} R_e C_f$$

$$\text{Blasius, } C_f = \frac{1.328}{\sqrt{R_e}}$$

(a) Trim, 4°.

Load coefficient, C_Δ	
⊡	0.85
○	2.13
□	4.26
△	6.39
▽	10.65
◇	19.17
▽	27.69
◁	36.21
△	53.25
◻	70.29
◿	87.33

(b) Trim, 6°.

(c) Trim, 12°.

(d) Trim, 18°.
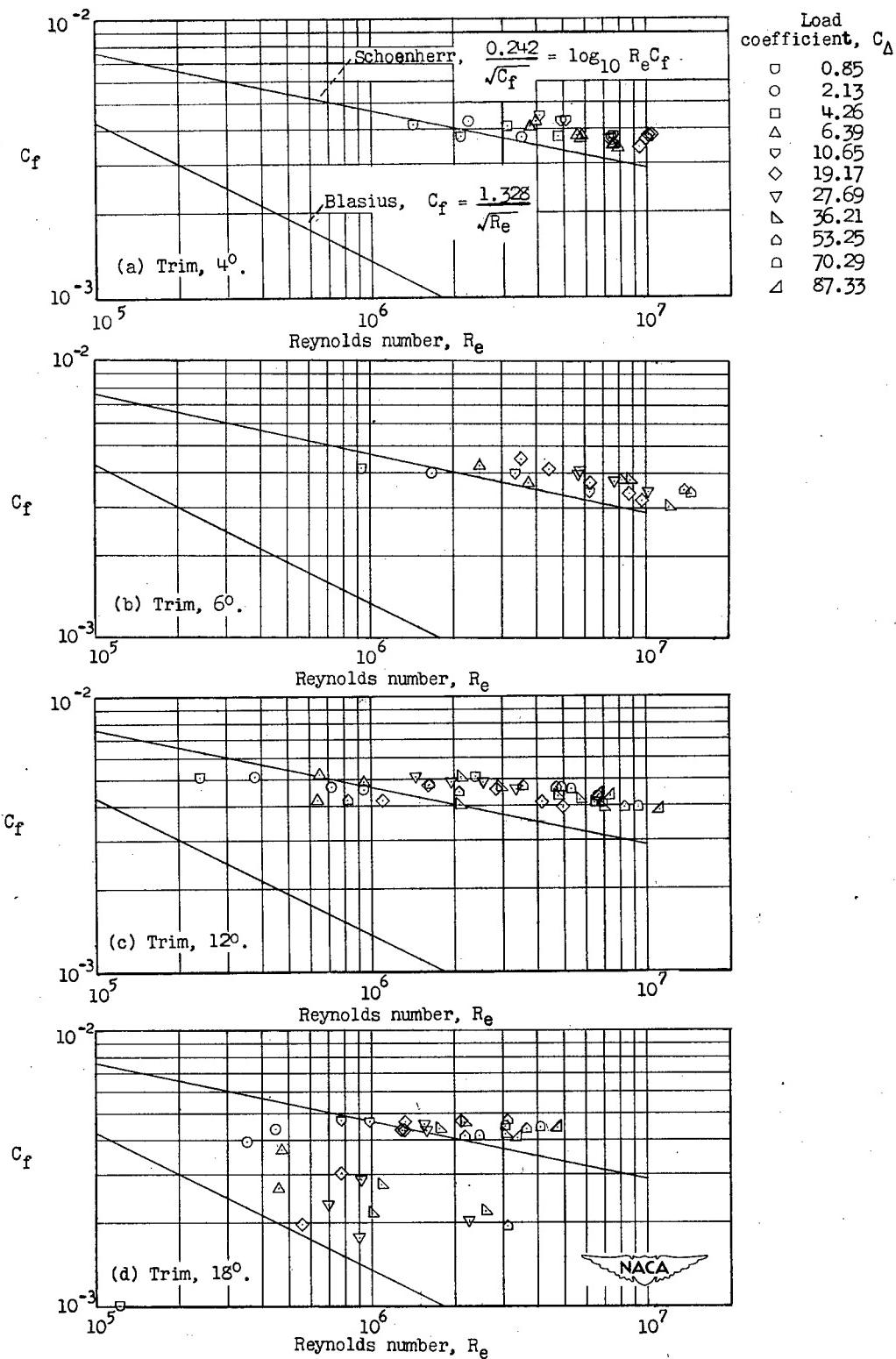
Reynolds number, R_e

Figure 14.- Variation of friction coefficient with Reynolds number.

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NACA TN 2842
National Advisory Committee for Aeronautics.
THE PLANING CHARACTERISTICS OF A SURFACE
HAVING A BASIC ANGLE OF DEAD RISE OF 40°
AND HORIZONTAL CHINE FLARE. Ulysse J.
Blanchard. December 1952. 26p. diagrs., photo.,
tab. (NACA TN 2842)

The principal planing characteristics of a surface
having an angle of dead rise of 40° and horizontal
chine flare are presented. The data indicate that at
a given trim the important planing characteristics
depend mainly on lift coefficient. The effects of in-
creasing the basic angle of dead rise from 20° (NACA
TN 2804) to 40° are to decrease the ratio of the
center-of-pressure location to the mean wetted
length, to decrease the extent of pile-up of water at
the keel, and to increase the friction drag.

Copies obtainable from NACA, Washington

1. Hydrodynamic Configu-
   rations - General
   Studies   (2.2)
2. Hulls, Seaplane -
   Length-Beam Ratio
                      (2.3.1)
3. Hulls, Seaplane - Dead
   Rise   (2.3.2)
4. Hulls, Seaplane -
   Chines   (2.3.6)
5. Planing Surfaces,
   Hydrodynamic   (2.6)
I. Blanchard, Ulysse J.
II. NACA TN 2842

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       rations - General
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2.   Hulls, Seaplane -
       Length-Beam Ratio
                                  (2.3.1)
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